ScuDo

Scuola di Dottorato ~ Doctoral School

WHAT YOU ARE,TAKES YOU FAR

XXXIV Cycle

Hardware Acceleration for Imaging Algorithms

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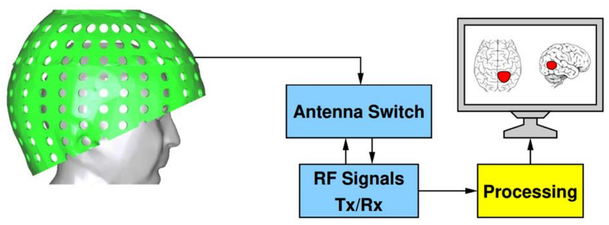
Research context and motivation

- **EMERALD**: **E**lectro**M**agnetic imaging for a novel gen**ER**ation of medic**AL D**evices
- Medical imaging plays a major role in accurate diagnosis and monitoring the evolution of diseases.
- **MRI, CT, PET**: Not portable, expensive, Harmful (CT only), different resolutions.
- **Microwave Imaging**: Low cost, Non-Ionizing (low health-risk), Excellent for soft tissue imaging, Portable.
- Different MI applications: breast cancer, brain stroke monitoring, thermal ablation, …
- Inverse scattering **MI reconstruction** algorithms: convert microwave radiations into image pixels. **Complexity** is the main problem in the majority of these algorithms.
- Analysis of MI reconstruction algorithms to find the "**computational kernels**" which are the bottlenecks of the design.
- **Hardware acceleration** of these kernels to reduce the total execution time compared to a software implementation.
- Whenever required, these accelerated kernels can be invoked from a host CPU, so the overall performance will be improved.

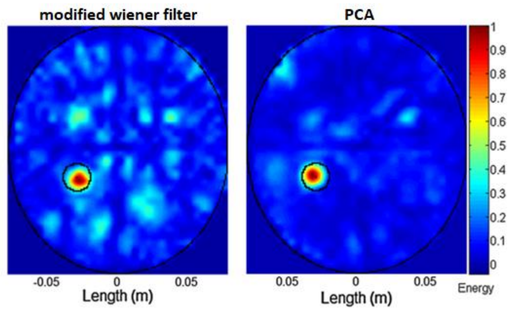
Microwave imaging system for brain monitoring

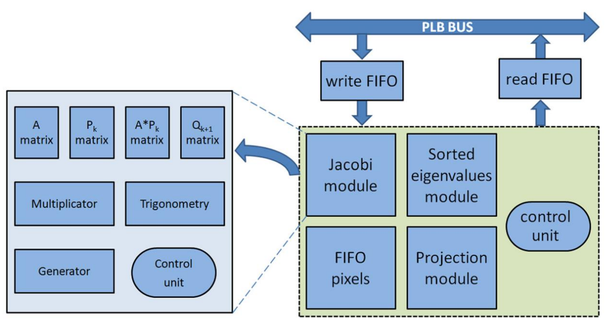


Addressed research questions/problems

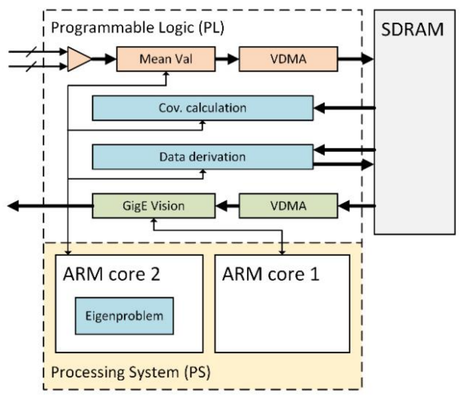
- SVD and PCA are commonly used in MI algorithms.
- To the best of our knowledge, there are no hardware designs for these algorithms specifically aimed at microwave imaging.
- **Hardware acceleration of PCA** (which includes SVD as an internal step) using **FPGA** is highly beneficial for MI algorithms.
- Previous FPGA designs of PCA have some drawbacks including one or more of the followings. They:
  - use manual RTL design which increases the total development time
  - are not efficient for large data dimensions
  - do not implement all the PCA steps (some steps are executed off-line)
  - are not flexible; only work for a specific data dimension and precision

PCA application in microwave imaging





Reference 1:
manual RTL design of PCA



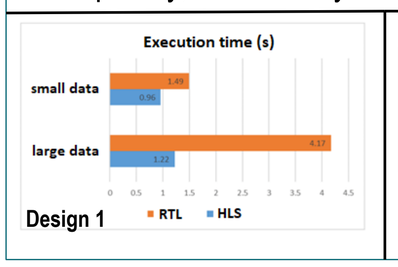
Reference 2 :
HLS design of PCA

Submitted and published works

- D. O. Rodriguez Duarte, **M. A. Mansoori**, J. A. Tobon Vasquez, G. Turvani, M. R. Casu, F. Vipiana, "*Development of an EM Device for Cerebrovascular Diseases Imaging and Hardware Acceleration for Imaging Algorithms within the EMERALD Network*", 13th European Conference on Antennas and Propagation (**EuCAP**), Krakow, Poland, **2019**, pp. 1-3.
- **M. A. Mansoori**, M. R. Casu, "*Efficient FPGA Implementation of PCA Algorithm for Large Data using High Level Synthesis*", 15th Conference on Ph.D Research in Microelectronics and Electronics (**PRIME**), Lausanne, Switzerland, **2019**, pp. 65-68.
- **M. A. Mansoori**, M. R. Casu, "*HLS-Based Flexible Hardware Accelerator for PCA Algorithm on a Low-Cost ZYNQ SoC*", Nordic Circuits and Systems (**NorCAS**) , Finland, **2019 (accepted)**.

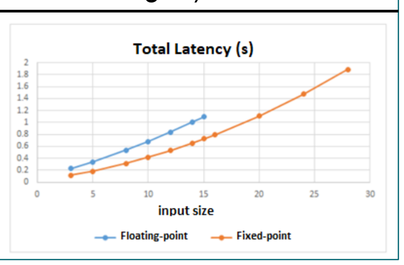
Novel contributions

- Designing a **flexible FPGA**-based **hardware accelerator** for **PCA** using High Level Synthesis (**HLS**), which can be used in Microwave Imaging.
- The flexibility allows us to use different data dimensions (including large data) and precisions. Fixed- and floating- point arithmetic are also supported.
- We argue that by using HLS the performance of the design is significantly improved compared with the conventional manual RTL design, in terms of resource usage, frequency, and latency. Two versions were presented (Design1 and Design2).



	latency (s)	%BRAM	%DSP48	%FF	%LUT
Ref(float)	1.1	12	19	38	73
Proposed (float)	0.83	4	21	17	46
Proposed (fixed)	0.53	5	39	10	24
Proposed SVD	—	5	13	13	21

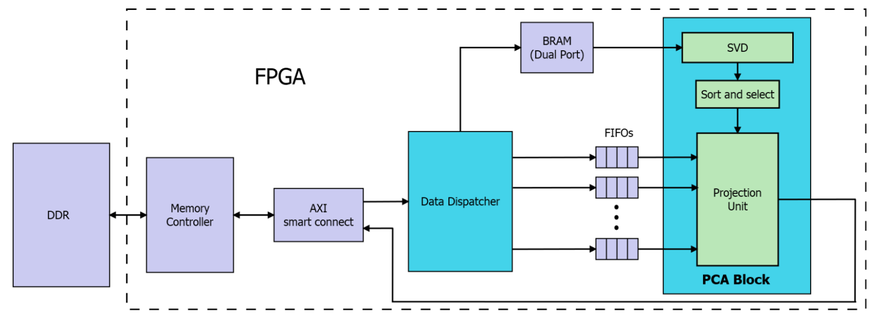
Design 2



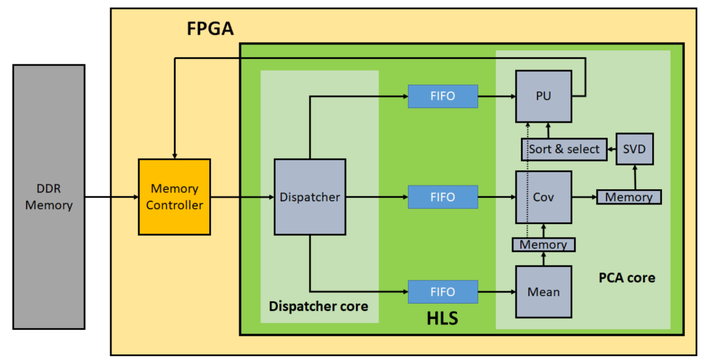
Adopted methodologies

- Vivado HLS tool 2018.2 for test and simulation
- Synthesis results for two FPGAs Virtex7 and Zynq7000.

Design 1



Design 2



Future work

- Hardware implementation of the proposed PCA accelerators on Zedboard (Zynq) and VC709 (Virtex7)
- Comparison of PCA accuracy by using a dataset of MI measurements
- Completing the library of computational kernels recurrent in MI algorithms
- Evaluating the best hardware platform to accelerate the execution of these kernels under various constraints (power, resource usage, latency, …) and different targets such as FPGA, GPU, multi-core CPU, ASIC.

List of attended classes

- 01MMRRV – **Advanced numerical techniques for the analysis and design of antennas**(03/14/2019, 33.33)
- 01TEVRV – **Deep learning** (06/04/2019, 50)
- 02LWHRV – **Communication** (09/17/2019, 6.67)
- 01RISRVA – **Public speaking** (09/17/2019, 6.67)
- 08IXTRV – **Project management** (09/17/2019, 6.67)
- 01QORRV – **Writing Scientific Papers in English** (03/28/2019, 20)
- **EMERALD core transferable skills** (02/12/2019, 20)
- **EuCAP 2019 Conference, short course** on "Microwave imaging for medical diagnostic applications: An introduction from theory to practical aspects" (05/04/2019, 3)
- **EMERALD general workshop** on "WIPL-D 3D full wave computational tool for modeling of medical microwave imaging scenarios" (05/20/2019, 21)
- **European School of Antenna** on "Diagnostic and Therapeutic Applications of Electromagnetics" (09/09/2019)
- **Secondment** at Keysight company, Linz, Austria (2019 June-July)

POLITECNICO DI TORINO

PhD program in

Electrical, Electronics and Communications Engineering